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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G06F 3/06	A2	(11) International Publication Number: **WO 99/35562** (43) International Publication Date: 15 July 1999 (15.07.99)

(21) International Application Number: PCT/IB98/02119

(22) International Filing Date: 28 December 1998 (28.12.98)

(30) Priority Data:
09/002,138 31 December 1997 (31.12.97) US

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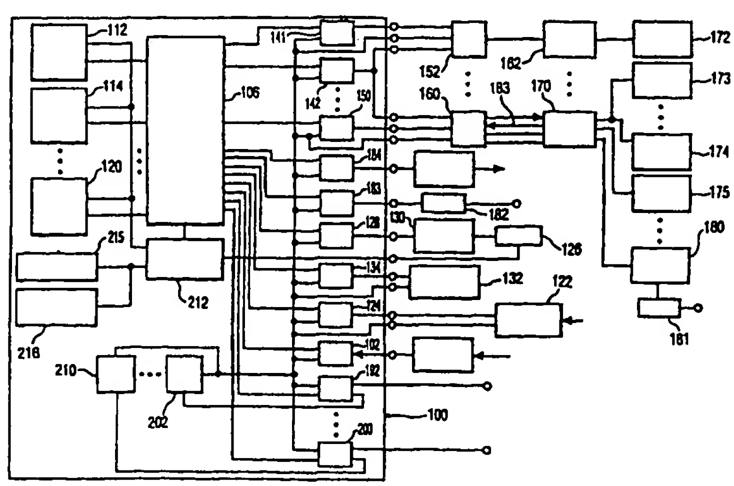
(81) Designated States: JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: INCREMENTAL ARCHIVING AND RESTORING OF DATA IN A MULTIMEDIA SERVER



(57) Abstract

In a video server, multimedia data for a production is archived with data blocks for a video disk file and data blocks for audio disk files and data blocks for auxiliary disk files all intermixed together in a single tape file, in approximately the same order required for producing a multimedia data stream. During restoring of the production, as the disk files are being copied to disk storage systems from the tape file, the data may be retrieved from the same disk files and played as a multimedia data stream as soon as enough information is available in the files to form the stream. Disk files are striped across a multitude of disk files systems, by a commutator, and a multitude of input/output units share access to all the files in all the disk file systems, for example, using a periodically switching round robin scheme or more complex scheduling. Also, during restoration, the same input/output unit of the server that is copying the data from the tape file to the disk drive may be used to play a multimedia data stream for the production and simultaneously other input/output units of the server are able to play multimedia data streams for the same production from those portions of the disk files for the production that have already been restored.

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INCREMENTAL ARCHIVING AND RESTORING OF DATA IN A MULTIMEDIA SERVER.

FIELD OF THE INVENTION

This invention relates to data archiving and restoring and relates most closely to the field of multimedia data servers.

BACKGROUND

In order to increase reliability of hard disk storage, computer systems used for critical, changing information commonly use a system known as a redundant array of inexpensive disks (RAID). In a RAID system, instead of being stored on a single hard disk, each data file is about evenly spread out across several data disks by a RAID controller card. In addition, parity information is written to a parity disk, so that if any single disk drive fails, there will be no loss of data or access to the data. Access to the disks is cycled across the data disks by the RAID disk controller and parts of each disk file is read or written in turn to each data drive. This allows a large number of smaller inexpensive disks to operate as though they were one large disk drive. This process of spreading the data across multiple devices is known as striping. Typically in a RAID system, the disk drives are networked to a disk controller card using a small computer interface (SCSI) peripherals network. Commonly available SCSI type RAID disk controllers access up to 13 data disk drives and one parity disk drive and inexpensive SCSI disk drives holding 23 GB (gigabytes = 1 billion bytes) are available thus providing up to 299 GB of highly reliable storage in one random access storage system (RASS).

The cost of high speed, random access, read/swite, storage devices is one of the major costs of computer systems. Because the cost of sequential access storage (including the removable media) is much lower per unit of storage than the cost of high access speed storage, it is common to move data (programs files and data files) which are not immediately needed onto removable media in sequential digital storage devices. The removable sequential media is then removed from the drive and replaced with similar media. This process of

temporarily moving files from random access storage devices onto media in sequential devices, and then removing the sequential media from the system, is known as archiving. When archived data are again required, then the media containing the data is loaded into the sequential device, and the files are copied back onto the high access speed storage devices in a process known as restoring the data.

Digital tape units are especially popular for backing-up and for archiving digital data because of the extremely low cost of tape. High quality tape units which write digital data at 3 million bytes per second (10 MBs) are commonly available. Tape capable of containing several hundred gigabytes of data are commonly available.

The invention is especially useful in the cable television industry. Cable television distribution has traditionally utilized semi-automated controls. Most cable distributors receive channels from program producers through satellite downlinks, video tapes, and dedicated lines. At the cable distributor, tapes are loaded into a VCR player, which is then manually queued and started to provide a program signal. Signals from the various program sources are routed from source cables by manually controlled switchers through modulators to provide each program at a different frequency channel, and the modulated signals combined into a distribution cable. This equipment used to provide the signals into the cable television distribution system, is commonly known as the head-end. For each channel with local commercials, a cartridge for each local commercial is loaded into a cartridge tape machine, which has been automatically queued and programmed to automatically play the correct local commercials on the correct channel at a particular time. The cable distributor may simultaneously distribute over 100 channels through a cable system.

Many cable operators are preparing to introduce multi-casting into their cable systems. In multi-casting, different programs and commercials are broadcast to different parts of the cable system or to different types of viewers (i.e. viewing customers). For example, different neighborhoods may receive programs specific to its demographics and receive commercials specific to its local businesses. Preferably, the same show could be broadcast at overlapping times depending on the commercials scheduled in the different portions of the cable system. Multi-casting requires a more automated approach since a different set of operations is required for each local area, so that many more simultaneous operations are needed.

Video servers, also known as multimedia servers, are a solution to the complexity of operating a multi-casting system. A video server can easily play the same or different local commercials on several different local portions of the cable system at

simultaneous or overlapping times. For example, local commercials may be loaded from tape into the disk storage of the video server, and the video server can be programmed to automatically play the correct commercial in the correct channel for each local area. Different programs can also be loaded into the video server to automatically play in different local areas at different or overlapping times.

For example, Philips produces Media Pool video servers which allow a large number of video production peripheral devices to simultaneously access a large number multimedia productions. Typical video peripherals include film scanners, frame editors, digital tape archival systems, video cameras, VCR units, program distribution links, and cable distribution systems (head-ends).

Instead of being stored on a single RAID hard disk system, each data file is about evenly spread out across multiple RAID systems called random access storage systems (RASSs). To give each video peripheral device access to all the data in all the RASSs, each device is connected to one or more input-output (I/O) ports. A computer controlled switching unit called the commutator then cycles the connections between the I/O ports and the RASSs, so that each RASS is regularly switched from I/O port to I/O port and the I/O ports are similarly switched from RASS to RASS. As the I/O port for a given device is cycled by the commutator across the storage systems, parts of the file are read or written in turn on each storage system. This allows a large number of peripheral devices to simultaneously have access to the same file without conflicts. This process of distributing files across all the RASSs is also referred to as striping. With RASS striping, a tape drive can back-up a video file while the same part or another part of the same file is being used by a frame editor and also the same or other parts of the file are being broadcast to different portions of a multi-casting cable system, for example.

For each production (program or commercial), several files of multimedia data must be stored in the RASSs of the video server. Typically, a single production requires a video file and up to four audio files. Furthermore, there may be several auxiliary files specifying additional information, including arrangement information and time code information describing how to arrange the information from the video and audio files to form a multimedia stream and when to broadcast portions of the information to play the stream.

In order to play the multimedia production, the time code, arrangement, video, and audio data must first be read from respective files that are stored in the RASSs. The video and audio data is then broadcast in a predetermined order at predetermined times according to the arrangement and time code information so as to play the multimedia data stream.

Successful operation of current multimedia servers requires careful planning. The loading or restoration of any required multimedia productions must be completed before the scheduled broadcast time. Furthermore, there must be sufficient random access storage space for restoring the required productions so that other productions that are not required at that time may have to be archived. Finally, restoration often requires other computer resources (e.g. I/O ports, tape drives, bandwidth through the commutator) which might not be available at all times.

Many cable systems offer a service known as pay-per-view in which subscribers who wish to see a special production can call a provider and order access to the production, often up to just a few minutes before the production starts. Typically, a small group of productions are repeated sequentially on a channel so that viewers who wish, may view the production at different times.

Many cable providers desire to offer an improved pay-per-view service known as near-video-on-demand, in which the same production is broadcast on multiple channels starting at staggered times, so that a viewer who desires to see a production and misses the start of the production will not have to wait through the entire length of the production before seeing the next available starting of the broadcast. If he misses the start on one channel he can see the start a short time later on another near-video-on-demand channel. In order to provide near-video-on-demand directly from tape, a multitude of copies of each production and a separate player for each channel will be required. Thus, it is economical to load such productions onto a video server which can simultaneously play different portions of the same copy of the production onto different channels.

Many cable systems are also preparing to offer a service known as video-on-demand in which any subscriber may request a particular multimedia production selected from hundreds or even thousands of available productions, and then the provider broadcasts the production to that subscriber viewer through an available cable channel as quickly as the production can be made available. Preferably, in addition to requesting play, the service should provide for viewer commands for so called trick play functions such as pause, frame-by-frame forward and reverse, slow motion forward and reverse, play in fast forward and reverse, very fast forward (wind) and reverse (rewind), and other multimedia manipulations currently provided by advanced VCR machines. Furthermore, the random access storage of a video server would allow providing random access viewer commands such as go to a scene or jump forward or backward a given playing time in a production, and similar functions provided on advanced DVD players. It would be prohibitively expensive to operate such a

system using a separate player and separate taped copy of a production for each potential simultaneous viewer in such a system.

Multimedia productions require large amounts of digital storage. One hour of programming of regular definition television, in motion JPEG format for instance, may require as much as 6 GB of storage, and video-on-demand customers may demand to select from thousands of hours of programming. Thus, it is not practical to store all of the desired productions in random access storage. Therefore, in a video server, most productions must be kept in archival storage, so that viewers who request an archived production must wait while the production is restored from archival storage.

Those skilled in the art are directed to U.S. patent 5,539,660 to Bird et al. describing a multimedia server with a cartridge tape unit. U.S. patent application 08/641,153 entitled "Advanced Data Server and Server System" describes another multimedia server. U.S. patent 5,305,438 describes a video storage system with an archival tape unit, and 4,949,187 describes a video server with an archival tape system. These above citations are hereby incorporated in whole by reference.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a multimedia data server requiring less critical planning for providing digital multimedia productions.

It is another object to provide a multimedia data server in which a digital multimedia production can begin playing essentially immediately upon selection at the same time that the production is being restored.

It is another object to provide a multimedia data server which is more convenient to operate.

It is another object to provide a multimedia data server in which a production is available for viewing while being restored from an archival copy.

In the invention disclosed herein, digital video, audio, and auxiliary files for a multimedia production are archived in an interleaved fashion, in approximately the same temporal order on an archival sequential access storage system (e.g. a tape drive) as the information is required for playing a multimedia data stream. During archiving, the system must first read the blocks of audio, video, and time code data from random access storage (e.g. a hard disk). The system then interprets the time code data so as to write the audio and video data to the tape storage in approximately sequential temporal order. Preferably, the

information is stored with additional information about the disk formatting and stored in a format so that the data can be easily transferred from a tape file to hard disk files, and then played from the random access storage almost immediately (as soon as enough data has been restored to read the files and to generate the beginning of a multimedia data stream).

In one embodiment, during restoration, the system first reads the blocks of the interleaved files in sequential format from the tape storage into a buffer. Then the system copies the data, reformatted to fixed size blocks, into a second buffer, and finally writes the fixed size blocks to random access storage. Preferably the data is restored at as high a rate as possible given the bandwidth restrictions of the tape drive and disk drive storage systems. At the same time, the system allows access to partially restored files in random access storage necessary to begin playing the multimedia production.

In another embodiment of the system, during restoration, blocks of data from the tape are copied into a buffer, and the data is formatted for a video stream. This formatted data is then stored in a second buffer from which a multimedia data stream can be played in real time. Preferably, the system also allows a higher speed restoration for fast-forwarding. At the same time, the data in the data stream, first buffer, or second buffer is converted into fixed size, formatted blocks for restoring to random access storage. This disk formatted data is then copied into an intermediate buffer from which the blocks are written to the hard drive system, thus, restoring the production. This allows the same I/O unit to simultaneously restore and play a production, and reduces the I/O traffic for the commutator and RASSs. Again, the system allows the files for the multimedia production in random access storage to be accessed and played, for example, by another video-on-demand viewer, as soon as sufficient portions of all the files of the production are restored onto the hard drives.

Both of these embodiments allow a viewer to access a production, archived as digital files (not as a multimedia data stream), almost immediately. Furthermore, they also allow other viewers to access the same production while it is being restored, without requiring multiple tape copies of an archived production. Finally, the system allows a production to be played during archiving by the same input and/or output unit used for the archiving. Again this reduces the number of I/O units and I/O load through the commutator and into the random access storage.

Those skilled in the art can understand the invention and additional objects and advantages of the invention by studying the description of preferred embodiments below with reference to the following drawings which illustrate the features of the appended claims:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a specific embodiment of the system of the invention for archiving the files of a multimedia production from hard drives to tape storage, interleaved approximately in temporal order, and for immediately playing the production as the files are restored.

Figure 2 illustrates a multimedia input and/or output unit for archiving and restoring the files of a multimedia production in a specific embodiment of the invention.

Figure 3 portrays another multimedia input and/or output unit for playing the production as it is being restored by another input and/or output unit.

Figure 4 shows details of a specific embodiment of the service controller of the invention for reading earlier portions of the files of a production as later portions are being written.

Figure 5 is a block diagram illustrating an embodiment of a random access storage system (RASS) of the invention for reading earlier portions of the files of a production as later portions are being written.

Figure 6 schematically shows a format for the files on a hard disks of the system of the invention before archiving.

Figure 7 schematically shows a format for the files interleaved on the archival tape of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawings, the same labels may be used in different drawings for similar methods or apparatus or different labels may be used. Also, communication links that do not have arrows may be bi-directional.

Figure 1 shows a specific example embodiment of a system of the invention, including a portion of video server 100 of the invention for archiving files of multimedia productions interleaved in about temporal order. The system receives multimedia data streams for productions from providers through input and/or output unit (IOU) 102. If required, analog to digital converter 104 is provided to convert the data stream from analog to digital form. As described below, the digital multimedia data stream is converted into fixed size blocks of data suitable for random access storage in video, audio, and auxiliary files. The blocks are

distributed by commutator 106 across multiple random access storage systems (RASSs) 112 - 120. JPEG video frames and possibly audio channels, may also be input or modified using production editor 122, and routed through IOU 124. The system also receives input from digital camera 126 through IOU 128 after conversion to a motion JPEG video stream in JPEG converter 130, if required. Finally, the system receives input of a motion JPEG video stream through film-to-digital-data converter 132 through IOU 134.

Commutator 106 may be any type of network of connections between two groups of terminals which allows for a cycling of connected terminals. That is, each terminal of the first group connects in turn with each of the terminals in the second group. Preferably the commutator is an M by N switching network, controlled by a service controller discussed below. Only one video server is shown with one commutator, but a server may include multiple commutators connected, for example, through a video switcher to the I/O units. Alternately, multiple video servers may be provided for one cable system with, for example, connections between several video servers and each head end.

Preferably, as described below in association with figure 5, each RASS includes a SCSI disk controller and up to 14 random access storage devices such as hard disk drives or optical disk drives, but other types of storage systems could be used. Herein, the term "disk" generally refers to any type of random access storage unit because disks are the predominate type of such random access storage units. Only a few RASSs are shown, but a typical video server should have a large number of such storage systems, limited only by the number of connections provided through the commutator. In a simple embodiment all the files of the system are striped across all the RASS's and the number of I/O units that can be connected equals the number of RASSs in a simple periodically-cycling, circular-shifting, round-robin connection scheme, so that, each IOU in turn accesses each RASS once in every cycle, and every IOU is connected to a different RASS, and every RASS is connected to a different IOU and thus, every IOU can potentially access all the portions of all the files during every connection cycle. Alternately, more complex storage and access scheduling can be provided to, for example, allow more IOUs than RASSs and different access periods for different IOUs depending on the I/O bandwidth requirements and criticality of the IOU's operation. Redundancy may be provided for the RASSs, but for video systems redundancy is not generally considered to be required since disk controllers are typically, highly reliable.

The multimedia data stream may be an analog NTSC or PAL video signal, a digital MPEG2 stream of packets, or a motion JPEG data stream. The provider may supply the production through a satellite downlink (not shown), through a dedicated line (not shown), or

by providing media (not shown) that are played on a VCR or other device (not shown). For clarity, only one IOU for receiving input from providers is shown, but a typical cable distributor may simultaneously receive input for over 100 channels from multiple inputs. Preferably, the video files are stored in JPEG format to simplify conversion for editing the production in production editor 122. Alternately, the video files may be stored in MPEG frame groups, for example, groups of 9 frames padded to make each group equal in size. The blocks of data for each of the files are striped across the RASSs. Preferably, at least one of the storage units provides redundant data to speed up access and/or prevent data loss.

Productions are played for cable service viewers by reading fixed size disk blocks for multiple files from a multitude of the RASSs 112-120 for each file, routing the data through commutator 106, converting the fixed size data blocks to a multimedia data stream in IOUs 142-150 and transmitting the data streams from the video server to one or more head-ends 152-160. The data streams are then routed to access control units 162-170 or nodes near one or more of the viewers, and then to multimedia terminals 172-180 for the viewing customers.

A separate head-end is provided for each independent area or for other grouping of subscribers of the cable distribution network, and each head end may have over 100 channel inputs. Even though many or even all of the channel inputs to the head-ends may be from the video server, only a few such inputs are shown for clarity. Typically, the data stream is routed from each head end to hundreds or thousands of local access control units, even though only one access control unit per head-end is shown for clarity. Between ten and five hundred viewers are typically serviced by each access control unit, but only one or a few per node are shown for clarity. Multiple viewer terminals 173, 174 may be connected to each output of an access control unit, and some households with multiple viewer terminals may use multiple outputs of the same access control unit. The viewer terminals allow selection and display of the multimedia productions.

In addition, the viewer terminals may provide for inputting access requests, inputting control commands, telephone connection, Internet connection, or even transmitting multimedia data back the video server. The terminal may include apparatus for requesting access to multimedia productions and controls for video-on-demand functions discussed above. The viewer terminal may include a camera and microphone (not shown) for video conferencing or for authoring multimedia productions. The viewer may be able to edit frames using the terminal, and to upload productions from a frame editor or VCR into private or shared storage in the video server for later viewing. A path may be provided from viewer

terminals back to the video server by the telephone system, the cable system or by some combination. For example, data may be transmitted through MODEM 181 to a telephone connection, then from another telephone connection through MODEM 182 and IOU 183 to video server 212 for access requests, control commands, and/or Internet page requests. Alternatively, transmission may occur through an available channel in the television distribution cable back to the access control units, then through a separate return cable 183 for terminal input back to the head end, and then from the head end to an IOU.

Multimedia productions may be provided to another production distributor such as another cable distributor, news network, or program provider through IOU 184 and digital to analog (D/A) converter 185, if required. Not shown are satellite up-link, dedicated cable, or VCR recorder to transmit the signal to the other distributor.

Data which is not immediately required may be archived from RASSs 112-120, through commutator 106, through IOUs 192-200, to sequential recording/reproducing units 202-210 for recording on removable sequential media (tape). The IOUs may have other connections for input or output, as previously described in relation to the other IOUs. Figure 2 shows an embodiment of the IOU 240 of the invention with a micro-controller 242 connected through a bus with memory 244 and input and/or output circuits (IOCs) 246, 248 and 250. The IOU is connectable at terminal 252 to the commutator through IOC 246, connectable at terminal 254 to a tape unit through IOC 248, and connectable to terminal 256 for I/O of a multimedia data stream through IOC 250. Preferably IOC 248 includes SCSI controller apparatus to operate one or more SCSI tape units, and the tape controller portion may be external or a part of the internal circuit as shown.

In an archiving process, program module 262 controls the CPU 242 and IOC 246 to request and receive fixed size file blocks formatted for random access storage from files striped across RASSs 112-120, and to store such file blocks into contiguous buffer 264 of memory 244. Program module 262 directs IOC 246 to request blocks of auxiliary, audio, and video data from disk files, as required to supply the data from buffer 264. Program module 266 controls the CPU to reformat or convert the blocks formatted for random access storage in buffer 264 into blocks formatted for sequential access storage, stored in buffer 268. In the conversion, the blocks for random access storage are copied into blocks of a different, preferably larger, fixed size for sequential access storage e.g. onto digital tape. Typically, tape blocks are several times larger than disk file blocks. Blocks from the video, audio and auxiliary files are all packed into the tape blocks and saved to tape in approximately the sequential temporal order that the information is required in order to play the production. The

information is stored so that the data can be easily unpacked from the tape blocks back into blocks for the hard drive. Then the data in buffer 264 that has already been converted is deleted to provide space for additional blocks from random access storage files. Program module 270 controls the CPU and IOC 248 to transfer the blocks from buffer 268 to one of the digital tape recorders 202-210 (shown in figure 1).

In one embodiment of the invention, at the same time that data is being archived from random access storage to sequential access storage, the data may also be played using the same IOU. Program module 272 controls the CPU to convert the data in buffer 264 from blocks formatted for random access into data for a multimedia data stream, and the data is stored into buffer 274. Then program module 276 controls the CPU and IOC 250 so as to play a multimedia data stream from buffer 274 through IOC 250. Preferably, at least parts of modules 272 and 276 are used for providing a multimedia data stream from IOC 250 when no archiving is occurring as in IOUs 141-150 and 184 in figure 1. Program module 277 which may be part of an operating system, controls the allocation of resources such as CPU time and access to buffer 264 to allow the archiving and playing in a multi-tasking manner.

In a restoring process, program module 280 controls the CPU and IOC 248 to request and receive blocks formatted for sequential access from one of the digital tape units 202-210, through IOC 248 and into buffer 268 for storage. Then program module 282 controls the CPU to convert the data from the sequential access blocks in buffer 268 into fixed size blocks for random access storage and to store the blocks into buffer 264. Program module 284 controls the transfer of the blocks of data from buffer 264, through IOC 246, through the commutator 106, (see figure 1) and to stripe the data across the disk storage systems 112-120. In another specific embodiment of the invention, at the same time that archived data is being restored from the tape drives to the hard drives, the same IOU can also play the multimedia production. Program 272 controls the CPU to convert the data in buffer 264 from blocks formatted for random access into data for a multimedia data stream, and to store the data into buffer 274. Then program module 276 controls the CPU and IOC 250 so as to play a multimedia data stream from buffer 274 through IOC 250. Program module 278, which may be part of an operating system, controls the allocation of resources such as CPU time and access to buffer 264, to allow the playing and restoration in a multi-tasking manner.

Preferably, IOU 250 is able to play a multimedia production when the same or another IOU is restoring archived data for the same production from one of the tape units to random access storage. Program module 262 controls the CPU 242 and IOC 246 to request and receive fixed size file blocks formatted for random access storage from files striped across

a plurality of RASSs 112-120 and to store such file blocks into contiguous buffer 264. Program module 262 includes section 286 for requesting file blocks as soon as sufficient blocks have been stored into files, striped across the random access storage system, to begin forming a multimedia data stream (i.e. while data is being written to the files, data is read from earlier portions of the files). Program module 262 directs IOC 246 to request blocks of time code data, audio data, and video data from disk storage, as required to supply data from buffer 264. Then as described above, program 272 controls the CPU to convert the data in buffer 264 from blocks formatted for random access into data for a multimedia data stream, and to store the data into buffer 274. Program module 276 controls the CPU and IOC 250 so as to play the multimedia data stream from buffer 274 through IOC 250.

In order to record a multimedia data stream, program module 290 controls CPU 272 and IOC 250 to receive the data from the stream, and program module 290 stores the data in buffer 274.

Figure 3 shows another embodiment 300 of an IOU for playing a multimedia production while another IOU is restoring the production from an archival tape system. IOU 300 includes embedded micro controller 302 connected through a bus with memory 304 and I/O processors 306, 308, 310 and 312. IOC 306 is connectable to commutator 106 (in figure 1) through input terminal 314, and IOC 308 is connectable to service controller 212 (of figure 1) through control terminal 316. IOC 310 is connectable to a destination for a multimedia data stream through output terminal 318, and IOC 312 is connectable to the multimedia destination to receive controls such as production requests, play, play in reverse, fast forward, rewind, pause, and goto scene or time.

– Program module 322 controls IOC 306 and the CPU so as to transmit requests for blocks of data, to the service controller 212 (see figure 1). The service controller schedules access through commutator 106 (see figure 1) and commands the storage systems to provide blocks of data through the commutator and input terminal 316 to IOU 300. Program module 322 then stores such blocks of data into buffer 324. Program module 322 includes apparatus 326 for accessing files which are in the process of being restored by another IOU. Typically, the request is for specific blocks from multiple files in the RASSs including video, audio and auxiliary files. Program 328 controls the CPU to convert the blocks formatted for random access storage, into data for providing a multimedia data stream stored into buffer 330. Program 332 controls the CPU and IOC 310 to receive service commands discussed above, from the destination viewer (not shown) through terminal 320 and IOC 312. Program module 332 communicates with other program modules such as program module 322, to provide the

requested services. Program module 334 controls the CPU and IOC 312 to provide the multimedia data stream from buffer 330, through IOC 310 and terminal 318 to the destination viewer.

Figure 4 illustrates some of the details of a specific embodiment of a service controller 350 similar to controller 212 of figure 1. Preferably, the service controller is a general purpose, high performance work station with a multitasking operating system and programs to continuously control the connections through the commutator and to service requests for file blocks from the IOUs. The multi-tasking operating system of the work station allows access to the CPU to be shared by several program modules taking turns one-at-a-time for a fraction of a second during each turn, so that operation of the programs appears to be simultaneous. The controller includes a central processing unit (CPU) 352 connected to electronic memory 354 and IOCs 356, 358, 360 and 362 connected with respective terminals 364, 366, 368 and 370. Program module 372 controls the CPU and IOC 356 to receive and transmit control signals to the IOUs. For example, the service controller may receive a request from one of the IOUs to read the files for a multimedia production. The files are each striped across a plurality of RASSs. Program module 372 conveys the request to program module 374 which schedules access through the commutator to read the files striped across the RASSs repeatedly sequentially in turn. Program module 374 controls the CPU and IOC 358 to communicate with the commutator. Program module 374 changes the state of the interconnection switches through the commutator in cycles so that during each cycle, each IOU has access to each RASS, across which files are striped, that the IOU needs access to.

Program 376 controls the CPU and IOC 360 to transmit control signals to control the I/O of the RASSs so that blocks of data are stored or retrieved at precisely the correct time in coordination with the settings of the access switches in the commutator and resulting connections with the IOUs. Program 378 provides a user interface for inputting management commands and displaying messages and reports from the service controller to verify receipt of the commands and describe the status of the system.

A portion 380 of program 372 accepts requests to read blocks of files for a multimedia productions which is currently being restored from archival storage. Preferably, portion 380 allows multiple files to be simultaneously written by one IOU and read by another IOU. Portion 380 keeps track of which parts of the files for a production have been written, allows access to the parts for which writing is complete, and denies access to the parts for which writing is not complete, and reports status back to the IOU. Program 374 has portion 382 which schedules access through the commutator for reading blocks of files when access

by another IOU has also been scheduled for writing blocks of the files. Program module 376 has a portion 383 which controls the operation of the RASSs so that blocks can be read from files for a production alternately with writing blocks to the same files.

The service controller is programmable to provide the programmed apparatus (program modules, data structures and data) of the invention. The controller can be programmed by introducing signals and writing the signals to ROM 385 or the fast RAM 354. The signals may be introduced to the controller through one of the IOUs or from one of the RASSs or by replacing the ROM in a socket of a circuit board (not shown) of the controller, or by inserting a ROM cartridge 386 such as a PC card into a PC card slot 387 of the controller. The programming signals can be introduced to the service controller by inserting replaceable media 388 such as a disk or tape into media drive 389 connected to controller 390. Alternately, the media drive may contain non-removable media and the drive is conveniently connectable /disconnectable from the controller. The media and drive cooperate to generate the programming signals. The signals can be introduced from another computer system 391 through a communication network 392 connected to IOC 393. For example, an Internet server can be connected through the telephone system using MODEM 394. In a similar manner the IOUs and/or RASSs may also be programmable in order to implement the invention.

Figure 5 illustrates an embodiment 400 of a random access storage system (RASS) of the invention. A system controller 401 may be connected through IOC 402 to communicate with the commutator 106 (see figure 1) and through IOC 403 to communicate with server controller 212 (see figure 1). The controller communicates through IOCs 404 and 405 with one or more groups of disk drives 406 and 407 respectively. Preferably, files are striped across a plurality of the disk drives with fixed size information blocks sequentially written to each drive of a parity group, and parity data written to a parity drive of the group so that if one of the drives of the group fails, the data is not lost, and system performance is not significantly degraded. Each drive such as disk drive 406 may be a magnetic hard disk, or a rewritable optical disk drive such as a DVD drive. An embedded controller (CPU) 409 is operated by programs in memory 410 which also contains buffers for holding data during I/O. Program module 411 controls the CPU to allow blocks of files to be read from the system as soon as a portion of blocks have been written to a file in the system.

Figure 6 will be used to schematically illustrate multiple files 500 of a multimedia production striped across multiple RASSs. Each RASS is represented respectively by one of the disks 501, 502, 503 and 504. This system is shown with only four RASSs even though there will typically be, a large number of RASSs. Only one disk is used to represent

each RASS even though each RASS typically has up to 14 hard drives, and each hard drive typically has 5 to 10 disks. The disks are shown with four tracks each holding only about 36 blocks each, but hard drive disks typically have thousands of tracks each holding thousands of blocks of data. Typically, each IOU is connected to each RASS one-at-a-time in turn through the commutator. Of course, if there are more IOUs than RASSs, then during each connection cycle each IOU will take some turns being idle. For example, if the bandwidth from the RASSs through the commutator into the IOU buffer is 40 MBs, but the IOUs only need 4 MBs of data, then a commutator allowing 10 times as many IOUs as RASSs is possible.

The number of information blocks accessed during each connection between switching of the commutator, depends on the connection time between switching and depends on the data rate through the system. In this example for illustrative purposes, an IOU will access five blocks of an RASS during each connection. When a multimedia data stream is received into an IOU, the stream is converted into blocks that are formatted for storage into files on the RASSs. The blocks from the IOU are transmitted through commutator 106 and striped across files on the RASSs. Most of the data will be stored in a video file, a small part of the data will be stored in audio files, and some of the data will be stored into one or more auxiliary files.

As an example, the first portion of a video file is written from a first IOU. The first IOU is connected to RASS 501 and five blocks V1-V5 are written to the RASS. At the same time a second IOU is connected to RASS 502, a third IOU is connected to RASS 503, and a fourth IOU is connected to RASS 504. Then the first IOU is connected to RASS 502 and another five blocks V6-V10 are written. Again at the same time the second IOU is connected to RASS 503, the third IOU is connected to RASS 504, and the fourth IOU is connected to RASS 501. Then the first IOU is connected to RASS 503 and anther five blocks V11-V15 are written, and then the first IOU is connected to RASS 504 and another five blocks V16-V20 of the video file is written.

Then, for example, a portion of the audio file for the production is written. The first IOU is reconnected to RASS 501 and five blocks A1-A5 of the audio file is written; then the first IOU is reconnected to RASS 502 and the next five blocks A5-A10 of the audio file is written; then the first IOU is reconnected to RASS 503 and the next five blocks A11-A15 of the audio file is written; and finally the first IOU is reconnected to RASS 504 and the next five blocks A16-A20 are written.

Then in a similar way, the first portion of the auxiliary file for the production is written striped across all the RASSs. The first five blocks X1-X5 are written to RASS 501;

then the next five blocks X6-X10 are written to RASS 502; then the next five blocks X11-X15 are written to RASS 503; and finally, the next five blocks X16-X20 are written to RASS 504.

Sequential portions of the files for the production continue to be striped across the RASSs until the production is fully loaded into the RASSs.

Figure 7 illustrates the files for a multimedia production that is archived interleaved in the tracks of a digital tape 550. Tracks can be written on the tape in many different ways, but is shown here for example, with slanted tracks produced by a rotating head similar to those produced by a VCR. Typically, the angle between the longitudinal direction of the tape and the track will be about 60, but is shown herein at a much higher angle to allow the contents of several tracks to be shown on this short segment. Typically, a large number of blocks of data will be recorded on each track, but again, the tracks have been shown with an exagerated angle so that the tracks appear relatively shortened and the blocks have been made large for illustration purposes so that each track is shown containing only three tape formatted blocks. Information from several blocks of random access storage formatted data is packed into each tape formatted block by an IOU, and the tape blocks are channel encoded and written into the tracks on the tape.

A single sequential access file 551 is stored in multiple tracks. In track 552, block 554 contains the data from disk blocks V1-V4 of the video file, block A1 of the audio file and block X1 the auxiliary file of figure 6. In this particular example, each tape block holds the data from six disk blocks, error detecting and correcting data, and some space 556 in the tape blocks is used to facilitate restoring the data to the disk files, for example, to identify the file for each disk block. The blocks are stored interleaved, as shown, in approximately the same temporal order required for generating a multimedia data stream so that when restoration of the files to the hard drives begin, the disk files very quickly contain sufficient data to allow the production to be played.

The invention has been disclosed with reference to specific preferred embodiments, to enable those skilled in the art to make and use the invention, and to describe the best mode contemplated for carrying out the invention. Those skilled in the art may modify or add to these embodiments or provide other embodiments without departing from the spirit of the invention. Thus, the scope of the invention is only limited by the following claims:

CLAIMS:

1. A multimedia system, comprising:

means (262, 246, 264, 266, 268, 270, 246) for archiving multimedia data from random access storage into sequential access storage;

means (280, 248, 268, 282, 264, 284, 246) for restoring the multimedia data from sequential access storage back into random access storage; and

means (272, 242, 274, 276, 250) for playing the multimedia data from the random access storage as the files are being restored from sequential access storage into random access storage.

2. The system of claim 1, in which:

the multimedia data in random access storage includes a multitude of files including at least one video file (V1-V40) and at least one audio file (A1-A40) and at least one auxiliary file (X1-X40) containing timing data for generating a multimedia data stream;

the data in random access storage is formatted into fixed size blocks (V1, A1, X1) of a first size and the data in sequential access storage is formatted into fixed size blocks (554) of a different larger second size; and

the multimedia data in sequential access storage (550) consists essentially of one file for each production with fixed size block of random access data from multiple random access files including at least one video file, at least one audio file and at least one auxiliary file interleaved into sequential access blocks in approximate the temporal order in which they are required for playing a production.

3. The system of any one of claims 1-2 in which,

the multimedia data in sequential access storage (550) includes additional information (A1-A40) for restoring the multimedia data into multiple files in random access storage (500).

4. The system of any one of claims 1-3 in which,

the audio files in random access storage (A1-A40) include 2 to 7 files, each file for producing a respective audio channel, the date for the multiple audio files being stored in separate blocks of data for restoring the random access files with the blocks of data interleaved in sequential access storage blocks.

5. The system of any one of claims 1-4 in which,

the video file in random access storage (V1-V40) contains multiple images in JPEG format and the sequential file contains multiple images in JPEG format.

6. The system of any one of claims 1-5 in which,

the means for playing the multimedia data include means (272, 264, 274) for building a multimedia data stream from multimedia data in random access storage blocks and means (276, 274, 250) for transmitting the multimedia data stream.

7. The system of any one of claims 1-6 in which the system further comprises:

means (272, 242, 264, 274, 276, 250) for playing the multimedia data as it is being archived from random access storage to sequential access storage; and

means (290, 242, 250) for receiving a stream of multimedia data into the system and storing the multimedia data in random access storage.

8. A multimedia system comprising:

means (272, 264, 274, 276, 250) for converting multimedia data in sequential access storage into a stream of multimedia data and for transmitting the multimedia data stream; and

means (282, 268, 264, 284, 246) for storing the stream of multimedia data into random access storage simultaneously as the multimedia data stream is being transmitted.

9. The system of claim 8 in which:

the converting means (272, 264, 274, 276, 250) includes means (282, 268, 264) for converting multimedia data formatted for sequential access storage, into multimedia data formatted for random access storage, and means (272, 264, 274, 250) for converting multimedia data formatted for random access storage into a stream of multimedia data.

10. A multimedia system comprising:

a multitude of random access storage systems (112-120);

means (212, 106) for storing data for a multimedia production, including multiple files (V, A, X) of first data blocks of a first fixed size with each file striped across a plurality of the random access storage systems (112-120);

means (272, 264, 274, 276, 250) for using information blocks of the multiple files for building a multimedia data stream for playing the multimedia production;

a sequential access storage system (192-200, 202-210); and

means (266, 264, 268, 270) for storing in the sequential access storage system, the data of the multiple random access files (V, A, X) for the production, interleaved into a single sequential access file (551) with the multimedia data in approximately the temporal order required for building the multimedia data stream and with a plurality of the first data blocks of a first size stored into second data blocks of a larger second size.

11. A multimedia storage system with archiving, restoring, and playing, comprising:

a network for multimedia data;

at least one disk controller (401) for receiving disk formatted multimedia data from the network and transmitting disk formatted multimedia data onto the network;

a multitude of disk units (406, 407) for storing disk formatted data from the disk controller, striped across a plurality of the disk units, and for retrieving disk formatted data from the plurality of disk units to the controller;

a tape controller (192-200) for receiving tape formatted data from the network, and for transmitting tape formatted data onto the network;

a group of one or more tape units (202-210) for storing sequentially formatted data from the tape controller onto removable tape in a process to archive the data, and for retrieving sequentially formatted data from the tape to the tape controller in a process to restore the archived data; and

a multimedia network server (100) including:

stream recording means (290, 242, 250) for receiving a stream of multimedia data into the system for recording the multimedia data;

stream playing means (276, 274, 250) for transmitting a stream of multimedia data out of the system for playing the multimedia data;

stream to disk means (292, 264, 274) for converting a stream of multimedia data into disk formatted data;

disk to stream means (272, 264, 274) for converting disk formatted data into a stream of multimedia data;

archiving means (266, 264, 268) for converting the disk formatted data into tape formatted data in a process for archiving the data;

restoring means (282, 264, 268) for converting the tape formatted data into the disk formatted data in a process to restore the archived data;

formatted output means (284, 268, 248) for transferring disk formatted data and tape formatted data onto the network;

formatted input means (280, 268, 248) for receiving disk formatted data and tape formatted data from the network; and

archival playing means (277) for converting tape formatted data to data for a first stream of multimedia data and simultaneously transmitting the data to play the first stream of multimedia data.

12. The system of claim 11, in which:

the system includes a plurality of disk controllers (401) each connected between the network and one or more disk drive units (406, 407);

the network includes a commutator (106) for striping disk formatted data for a production across a plurality of the disk controllers;

the archival playing means (277) includes means for controlling the restoring means to ~~e~~onvert data for a multimedia production from sequential access storage formatted data to random access storage formatted data and simultaneously controlling the disk to stream means to convert disk formatted data for the same production to a stream of multimedia data to permit playing an earlier portion of data for a multimedia production in real time while data for a later portion of the same multimedia production is being converted from sequentially formatted data to disk formatted data, transmitted through the network, striped across the disk controller and striped across the disk drives connected to each controller.

13. The system of claim 11 or 12, in which:

the restoring means (282, 264, 268) include means for converting the sequentially formatted data into the first stream of multimedia data and means for converting the first stream of multimedia data into disk formatted data; and

the archival playing means transmit the first data stream to play the first data stream simultaneously as the first data stream is converted into disk formatted data.

14. The system of any one of claims 11-13, in which the archiving means includes means to convert the disk formatted data into a second stream of multimedia data and means to convert the second stream of multimedia data into sequentially formatted data; and

the system further comprises means to transmit the second stream of multimedia data from the system simultaneously during the conversion of disk formatted data to sequentially formatted data.

15. A method of operating a multimedia data storage system, comprising the steps of:

first reading archived multimedia data for a production from sequential access storage (202-210) in a sequential access format;

first converting of the sequentially formatted multimedia data for the production into random access formatted multimedia data;

writing the random access formatted data for the production, into at least one random access storage unit (112-120) to restore the archived data; and

second converting of the multimedia data for the production into a multimedia data stream for playing the production, simultaneously as the reading from tape, first converting, and writing to disk steps are performed.

16. – The method of claim 15, further comprising the steps:

reading multimedia data from the random access storage (112-120) (410) of the network in a disk format;

third converting of disk formatted multimedia data to sequentially formatted data onto the network;

writing the sequentially formatted data into the sequential access storage; and fourth converting of the disk formatted data to a multimedia data stream for playing multimedia data, as the reading from disk, second converting, and writing to tape steps are performed.

17. A method of converting sequentially formatted data on a network into disk formatted data on the network, comprising the steps of:

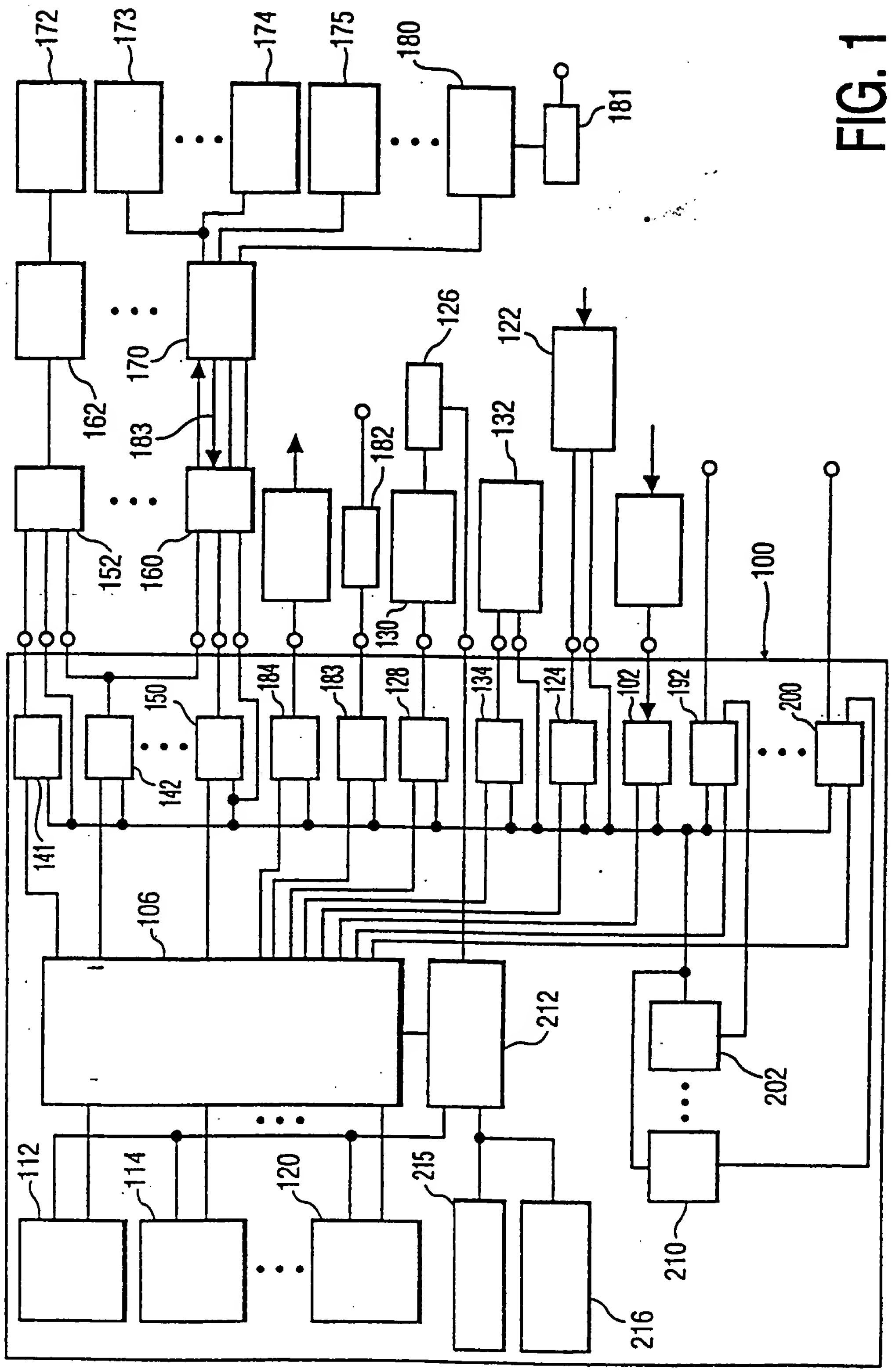
converting the sequentially formatted data from the network into a multimedia data stream; and

converting the multimedia data stream into disk formatted data onto the network.

18. A system to program a video server, comprising: apparatus (388, 389, 385, 386, 391, 392, 393) to provide programmed means for playing a multimedia production as disk files for the production are being restored from sequential access storage of the server into random access disk storage of the server.

19. The system of claim 18 in which:

the apparatus includes one or more of: removable computer media (388) for inserting into a drive of the server; a removable storage unit (389) for connection to the server; permanent memory (385) for inserting into a socket of the server; a memory cartridge (386) for inserting into a slot of the server; a computer network of one or more computers (350, 191) and one or more communication pathways (392, 394) for signal communication with the server.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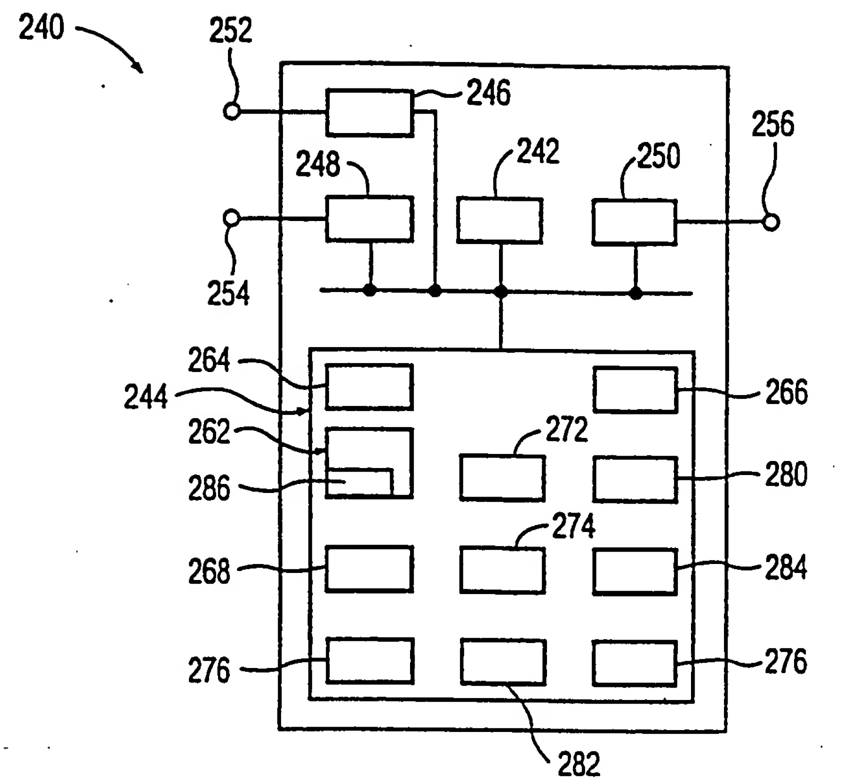
215
210
216

FIG. 1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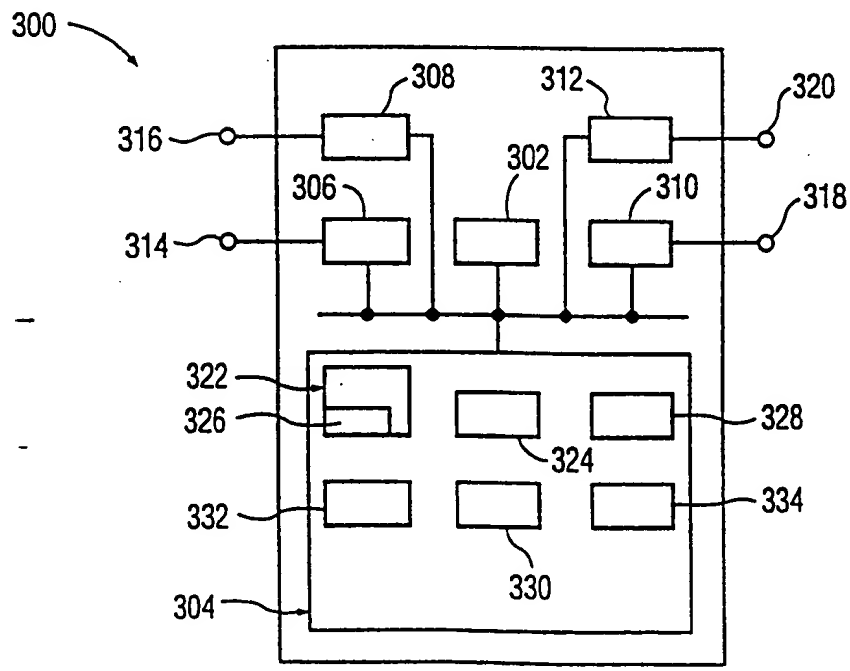
282

FIG. 2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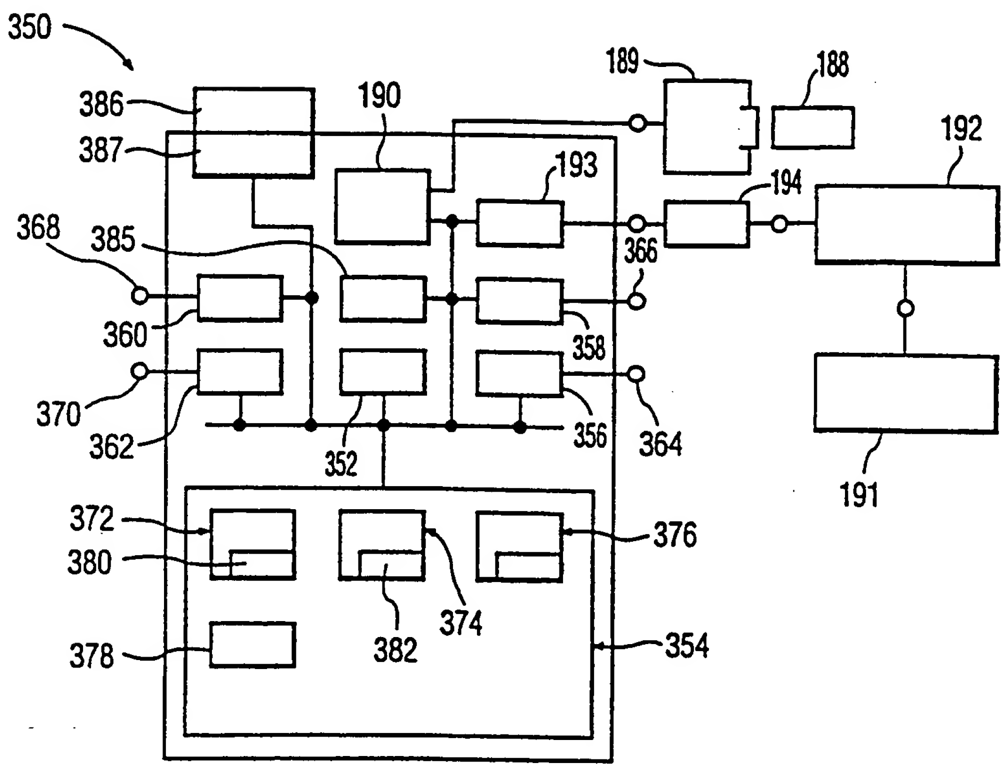
330
304

FIG. 3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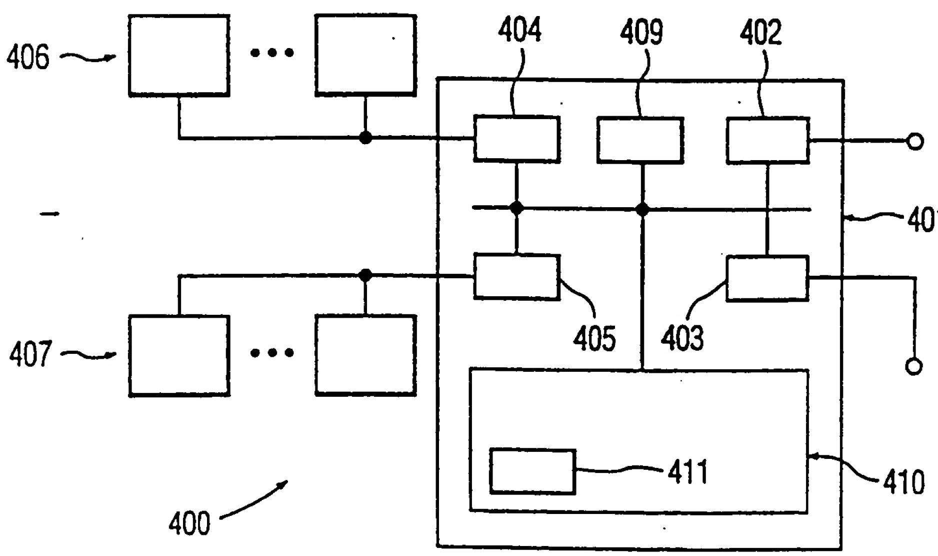
380
376
374
382
378
354

FIG. 4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404
409
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401
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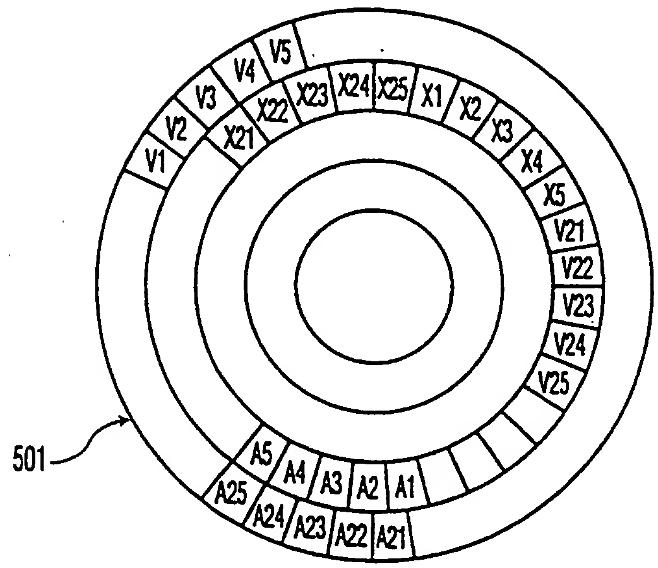
405
403
411
410
400

FIG. 5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V2
V3
V4
V5
X21
X22
X23
X24
X25
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X2
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X4
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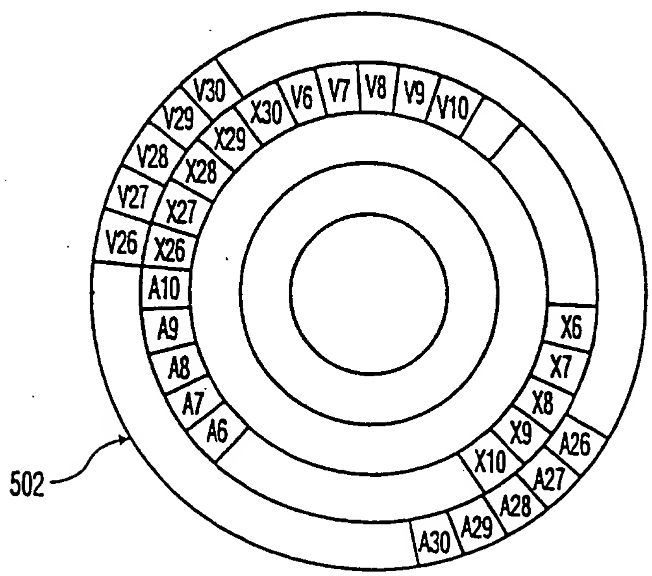
V21
V22
V23
V24
V25
A5
A4
A3
A2
A1
A25
A24
A23
A22
A21
501

FIG. 6A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V27
V26
X30
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V7
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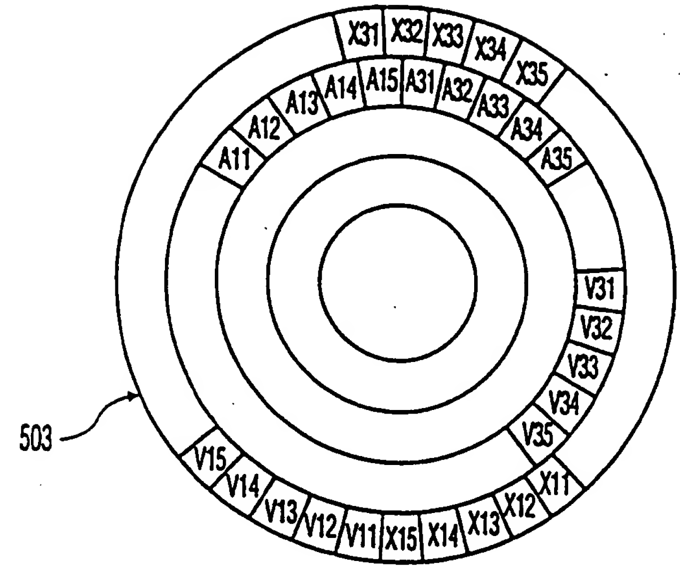
X29
X28
X27
X26
A10
A9
A8
A7
A6
X6
X7
X8
X9
X10
A26
A27
A28
A29
A30
502

FIG. 6B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X32
X33
X34
X35
A11
A12
A13
A14
A15
A31
A32
A33
A34
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V31
V32
V33
V34
V35
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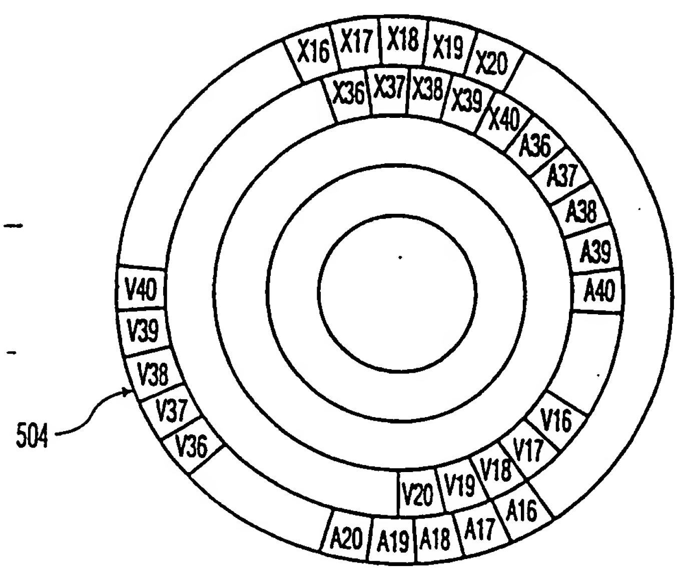
V15
V14
V13
V12
V11
X15
X14
X13
X12
X11

FIG. 6C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X17
X18
X19
X20
X36
X37
X38
X39
X40
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A37
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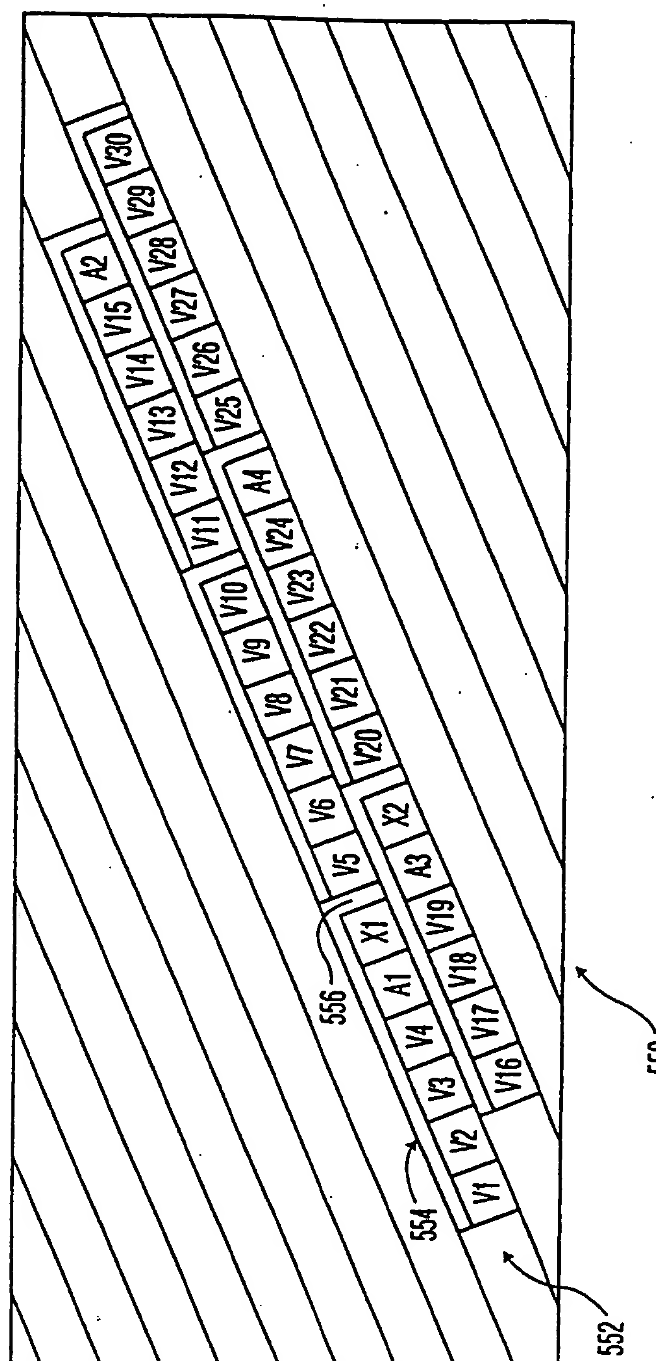
A39
A40
V40
V39
V38
V37
V36
504
V16
V17
V18
V19
V20
A20
A19
A18
A17
A16

FIG. 6D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V11
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V9
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V7
V6
V5
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V2
V1
V30
V29
V28
V27
V26
V25
A4
V24
V23
V22
V21
V20
X2
A3
V19
V18
V17
V16
556
554
552
550

FIG. 7